Center for Integrated Nano-Technologies

Operating Procedure for Trion Minilock III and Orion III Etch and Deposition Systems

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1. PURPOSE

This OP is used to alert personnel to the potential hazards and operating procedures associated with the setup, operation, and routine maintenance of the Inductively Coupled Plasma Reactive Ion Etch and Chemical Vapor Deposition systems.

Inductively Coupled Plasma Reactive Ion Etch and Chemical Vapor Deposition systems are in CINT to generate a low-pressure gas plasma. Species generated in the plasma (ions, neutrals, and electrons) are used to pattern and deposit material for the fabrication of microelectronic and optoelectronic devices. Ions formed in the plasma are accelerated to the cathode on which the substrate is located and results in either anisotropic etching or deposition.

Inductively Coupled Plasma Reactive Ion Etch and Chemical Vapor Deposition systems are very versatile machines that can be used to etch and deposit a variety of materials based on the plasma chemistries incorporated. It is impossible to cover all the conditions under which the ICP RIE and CVD reactors can be operated. This makes it imperative that the ICPs be operated only by personnel that are fully trained to recognize potentially hazardous conditions and qualified to respond to these conditions. Additionally, this OP must be updated to include hazards that are identified in new processes.

This OP covers the operation of the ICP reactors located in the CINT, building 518, and all auxiliary equipment necessary to run the ICP reactors. The ICP reactor may consist of a vacuum system, gas-handling system, radio-frequency (RF) generators (400 kHz and 13.56 MHz), solid state electronics, water cooling, plasma chambers, pneumatic air valves, interlocks, and front panel controls and indicators.

2. ACRONYMS

Many pieces of equipment and procedures are known almost exclusively by their associated acronym, it is important to become familiar with the following list to avoid confusion.

SNL- Sandia National Labs
CINT- Center for Integrated Nano-Technologies
SOP/OP- Standard Operating Procedure/Operating Procedure
LEL – Lower Explosive Limit
PEL – Permissible Exposure Limit
ICP Reactor – Inductively Coupled Plasma hybrid reactor
RIE – Reactive Ion Etch
CVD – Chemical Vapor Deposition
ES&H – Environmental Safety and Health
S&S- Safeguards and Security
QA- Quality Assurance
PM- Preventative Maintenance
UV- Ultra Violet
HV- High Voltage

3. DEFINITIONS

Authorized User- Personnel with the required training and subsequent approval of the CINT Key Operator to use said equipment.
Key Operator- Designated Key Operators are qualified to perform tool specific training of Authorized Users, and are responsible for the maintenance of the equipment.
IL User - Personnel trained in the cleanroom overall safety and gowning procedures, but not authorized to operate equipment.
ES&H Officer – Provides ES&H, S&S, and QA for CINT activities.

4. RESPONSIBILITES

It is the responsibility of every employee, contractor, and visitor to ensure a safe and healthy working environment. There is no experiment or procedure at Sandia that is so urgent that it needs to be done in an unsafe manner, and it is everyone's obligation to refuse to do work that he or she believes to be unsafe. If there is an activity or situation that is of concern it is their immediate responsibility to contact a supervisor or ES&H representative.

Key Operator - Key Operators are fully trained in operation of the ICP reactor and are qualified to approve authorized users and operate the ICP reactor in both standard and non-standard modes. Key operators are authorized users and must follow the responsibilities of an authorized user. Key operators are responsible for maintaining the ICP reactors and performing minor repairs. The key operator must also assure that the ICP reactors are operated by authorized users only.

Authorized User -Authorized Users are trained and approved by the key operator or authorized designee in the operation and the safety of the ICP reactor. They are qualified to operate the ICP reactor in the standard mode only. Authorized users have the responsibility to halt use of the ICP reactor if a hazardous condition exists that endangers themselves, others in the lab, or the environment. Authorized users are also permitted to train others with the permission of a key operator.

5. TRAINING

Prior to using any Integration Lab tools it is necessary to complete the general, site, and tool specific training. The training required for the operation of any of the Trion tools is listed below.

5.1 Corporate Level General training

CINT personnel shall complete the following Corporate-required training courses prior to using the ICP. This list may not be inclusive, so refer to the training section of the PHS associated with the ICP for additional information.

- ESH100 - Laboratory Standard Information and Training
- CHM100 - Site Specific Laboratory Safety Training
- PSO – Pressure System Operator Qualifications Form
- ENV112 - Hazardous Waste and Environmental Management Training

5.2 Site Specific training

In addition to corporate-level training, site specific training shall be completed. These courses are administered through either the clean room manager or a qualified user of the equipment.

- Site Specific Training for Unescorted access to the Integration Lab
- Site Specific Training for Personal Protective Equipment
- Site Specific Training - Non-Ionizing Operation Specific

5.3 Tool Specific training

Once all corporate and site specific training has been completed, the user must schedule a walk through and training session with the Key Operator of the tools that shall be used. The user may contact John Nogan or Catherine Mombourquette for scheduling.

6. APPROVAL, NOTIFICATIONS, SCHEDULING

After reading and signing all applicable OP's, finishing all associated training including hands on training from the Key Operator or approved alternate the user will be free to use the tool as needed. The authorized user will then be given access to schedule the tool in the on-line tool calendar located at: www.google.com/calendar .

Google Calendar Passwords:

Trion CVD tool Email: cintcvdicp Password: 1527cvdicp
Trion Cl ICP tool Email: cintcletch Password: 1527cletch
Trion F ICP tool Email: cintfetch Password: 1527fetch

7. SAFETY PRECAUTIONS AND LIMITATIONS

This section describes hazards identified with the ICP reactor and the actions taken to alleviate those hazards. The hazards are contained by the design features provided by the manufacturer and are insured by proper operating procedures.

There are several major hazards to personnel:

- Thermal Hazards

- Electrical Shock
- Compressed Gas Hazards
- UV Burn Hazard/ UV-Light or Non-Ionizing Radiation Exposure
- Mechanical pinch hazards

During normal operation, the CINT Trion ICP Systems are an inherently safe tool and has limited possibility of exposure to hazards. Only the CINT Key Operator(s) may open the tool or perform maintenance. However, to better inform the user we have included the following information on the internal hazards of the tool.

7.1 Thermal Hazards

Internal surfaces of the system and the substrates may become heated during operation to temperatures that can cause severe skin damage due to thermal burns. Substrates must be handled with tweezers or vacuum wands. The platen or carrier may also be quite hot and must be handled with tweezers or high temperature gloves and a sign indicating hot surfaces are present when the ICP reactor is operated under conditions that produce substantial platen heating. The exterior of the equipment does not become hot.

7.2 Electrical Shock

Electrical hazards are present in the ICP reactor. There is a potential for producing lethal electrical shocks as well as the potential for electrical arcing and fire. These hazards are contained by multiple levels of interlocks, shielding, and controls. If the system requires maintenance or troubleshooting where the exterior panels are removed, proper lockout/tag-out procedures must be followed.

Power supplies are used to power electronics, create plasmas, and operate mechanical pumps. Failure to follow recommended electrical safety precautions (all high voltage sources marked clearly, proper grounding straps, shielded device connections, and no frayed cords) could result in severe injury or death. Any electrical troubleshooting of the system must be done by qualified personnel as authorized by CINT management and according to safe procedures when working with high voltages. High voltage electrical repairs will not be performed alone. Only trained personnel as authorized by CINT management are permitted access to the service areas of the ICP reactor. Servicing of the system will take place only when two people are present.

The remaining high voltage or high current power supplies employ shielding to prevent contact with dangerous regions of the supply without first removing the shields. Before removing the outside protective panels, disconnect the appropriate circuit breaker on the main power distribution panel.

The ICP reactor is equipped with an Emergency Power Off switch. All valves on the system are of the normally closed type, meaning that if the power is suddenly lost, all valves will close and no gases will enter the chamber or atmosphere.

7.3 Compressed Gas Hazards

Several gases can be used with the ICP reactor. These gases include but are not limited to the following: Chlorine (Cl_2), Boron Trichloride (BCl_3), Nitrogen (N_2), Helium (He), 100% Silane (SiH_4), Ammonia (NH_3), Nitrous Oxide (N_2O), Argon (Ar), Oxygen (O_2), Sulfur Hexafluoride (SF_6), and fluorocarbon etch gases ($C_xF_yH_z$). The facility gas panels or cabinets are equipped with pressure relief valves or pressure sensors as specified by Sandia safety procedures. The primary hazard associated with a chlorine-containing gas is its toxicity. Anyone exposed to any toxic gas should be transported to the nearest medical facility as soon as possible. The primary hazard of SiH_4 is that it is pyrophoric and can ignite spontaneously in air. Some of these gases are oxygen displacers only (Ar, N_2, SF_6, and He) and do not pose toxicity hazards.

High purity nitrogen is used to vent (bring to atmospheric pressure) all segments of the system. The stainless steel UHV system can withstand >20 psi without a safety hazard. However, zero profile glass, quartz, or sapphire viewports are incorporated into the system. The explosion limit of these is <30 psi. The explosion of a viewport could result in

severe injury including blindness or death. Control measures for over-pressurization of the system are the chamber doors that release when the pressure reaches atmosphere.

Handling and storage procedures for compressed gases are presented in the ES&H Manual. Familiarity with these procedures minimizes the possibility of accidental releases of toxic gases and exposure of personnel to harmful levels of these gases.

7.4 Chemical Gas Hazards

Chemical substances may be present in the ICPs in the form of etch or deposition byproducts. Chemical substances from these processes are found as absorbed residue on the vacuum chamber walls and etched substrates. These chemical substances are contained within the vacuum chamber walls and etched substrates. These chemical substances are contained within the vacuum chamber during operation. ICP user's must be protected against skin contact with the chamber walls and etched and deposited wafers and therefore must wear cleanroom gloves and use tweezers or vacuum wands when handling the wafers. Maintenance personnel and authorized users must wear appropriate person protective equipment when working on surfaces exposed to the plasma. When working with the ICP, gloves and safety glasses must be worn, with additional protective equipment sued as required by the OP for Acid, Bases, and Solvent Wet Stations (see appropriate OP's).

All etch and deposition byproducts or fluids generated by or used to maintain the ICP reactor must be considered hazardous and handled according to the standards west by Sandia ES&H. the materials generated during an etch or deposition are not well-defined and must be handled as hazardous. Because GaAs contains inorganic arsenic compounds, it is classified as a known human carcinogen and therefore etch and deposition byproducts and fluids used in this machine must be handled as carcinogens as outlined in the Acid, Bases, & Solvent OP.

Fluids used in the pump package (Fomblin) of the ICP reactor are hazardous. The vacuum pumps operate in environments contaminated by toxic gases and etch and deposition byproducts. These toxic substances may be absorbed through the skin; therefore personal protective equipment must be used when handling the fluids. The fluids are of the PFPE-type and can be reclaimed by returning the used portion to the distributor in accordance with the shipping procedures outlined by the distributor.

7.5 Mechanical pinch hazards

Any equipment that has moving parts will have some sort of pinch hazard. The mask ICP has several moving pieces. It is important to be alert when working near moving parts.

7.6 Gas Release Hazard

The system is equipped with interlocks which prevent the flow of process gas without adequate vacuum. The vent option is only available when the process gas flows are off. Provisions are also included in the operation procedures that a pump-purge cycle be used following each process.

7.7 Non-Ionizing Radiation Hazards

Radiation hazards present with the ICP reactors are:

a) Radio-frequency energy, 100-120kHz at 300W, 13.56MHz at 500W and 1300W, are all capable of producing burns or other tissue damage.
b) Visible laser light at 670, <1mW with a low hazard potential; could cause an aversive blink response.
c) Exposure to UV light from the optical emission of plasma.

System design controls radiation leakage outside the vacuum system. UV light may be produced by the plasma, it is important to minimize escape of UV light from the system, and wear protective eye wear when appropriate. Prolonged exposure to UV light can cause inflammation of the cornea and can induce cataracts.

8. SPECIAL TOOLS, EQUIPMENT, PARTS, AND SUPPLIES

- 100mm Carrier Substrate – Samples less than 100mm in diameter must be mounted to a carrier substrate in order to be loaded into the reaction chamber. Sample can be secured to the carrier using single side adhesive Kapton tape. Double side adhesive Kapton (Polyimide) tape, carbon tape, or Mung II (UHV Heat Sink Compound) can also be used to bond the sample to the carrier. Photoresist is the best all around choice for sample bonding in the etch systems however due to temperature limitations it must not be used in the CVD chamber.

  Note : The combined thickness of the carrier, bonding agent and sample must not exceed 2.5 mm.

9. SYSTEM OPERATING AND MAINTENANCE PROCEDURES

Operation of the ICP reactor is to be performed by trained and authorized personnel. Normal operation of the ICP reactor is performed following the procedures outlined in this document and in the ICP reactor Instruction Manual. Since the ICP reactor is protected by interlocks and protective fastener-secured panels, it can be operated by an authorized user without additional observation.

9.1 Set-Up and Preparation

Upon arrival the ICP should be in standby mode. Verify the following before running a process:

- Vacuum – Verify that the vacuum pump oil level is near the middle of the sight glass. If the vacuum pump requires oil, contact a key operator or facilities person.

- Process Gas – Verify that all process gases necessary are available and that the gases will be supplied at the correct pressures. If any gas is incorrect, contact key operator or facilities person. Do not adjust any regulator without the approval of a key operator.

- Ventilation – Verify that the CINT exhaust system is operational before any processing is done in the ICPs.

- Chilled water – Process chilled water must be available to the ICP reactor prior to operation. Process chilled water inlet pressure must be 60 to 80psi and the outlet pressure must be 10 to 20psi. Check the process chilled water gauges located in the 1528 chase.

9.2 Operational Procedure

Materials/Conditions to avoid –

1) Load dummy wafer into process chamber and put system into "Standby" mode when finished processing.
2) To avoid contact with clamp ring, ***sample + carrier thickness must not exceed 2.5 mm***.
3) Verify that the ***back of the wafer or carrier that contacts the end effector is clean*** before loading.
4) Keep hands clear and materials away from load lock lid during transfer operations.
5) Limit ICP power to 700 watts and RIE (Bias) power to 50 watts.
6) Verify matching transformer tap position before operating in triode (HDP) mode.
7) Never strike plasma without a wafer in the process chamber.
8) Use standard LS and HD recipes only, do not adjust gas flow ratios or process pressure. Process window is very narrow. Slight adjustments in ICP power can be used to lower stress.

Operating Screens/Functions

- **Standby Mode:** Displays reaction and load chamber pressure purge gas flow (if applicable) while system is in standby.
- **Trion – (Main System Menu)**: Top level screen, contains links to Load/Edit Recipe, Download Recipe, Unload Wafer, Load Wafer, Manual Process Control, Automatic Single Process, Hardware Setup, Maintenance, Operator Login, Standby screens. The Exit program function is also present on this screen.

- **Load/Edit Recipe:** Allows operator to view current recipe, create new recipe, load and save recipe to disk. Please note that this is just the editor, program displayed may not run correctly unless "Download Recipe" is selected when prompted during editor exit.
- **Download Recipe:** Transfers the program file from the recipe editor to the run buffer. System will only execute the program that resides in the run buffer.
- **Load Wafer:** Initiates a load wafer transfer sequence if a wafer is not in the process chamber.
- **Unload Wafer:** Initiates an unload wafer transfer sequence if a wafer is in the process chamber.
- **Manual Process Control:** Allows process variables to be adjusted real time, machine control is completely manual.
- **Automatic Single Process:** Executes process currently loaded in run-recipe buffer.
- **Automatic Single Process:** If a wafer is not loaded in process chamber, this function provides a means to automatically load process and then unload with minimal operator intervention.
- **Log On/Off:** Controls access to certain system screens and functions. If logging in under another user name, you must log off the current user before logging in under the new user name. ***Default User Name: cint , Default Password: cint.***
- **Hardware Setup and Maintenance:** For authorized personnel only.
- **Standby Mode:** Places tool into standby operation. Tool should be placed into in standby when not in use.
- **Exit**: Closes system control program. Normally the system control program is left running at all times.

System Operation

Load/Unload Wafer

1) Load Wafer (Wafer not in Process Chamber)
    a. Select <Load Wafer> (Trion Main System Menu).
    b. When asked if you "wish to VENT the load lock first" select <Vent Lock First>. Load lock vents for 60 seconds before opening lid. Lid opens automatically, keep hands clear and materials off of load lock lid during wafer transfer operations.
    c. "Wafer Load Sequence" appears, place wafer onto end effector, align flat and edge of substrate to black line on the end effector. Select <OK> to proceed with transfer and <Cancel> to abort transfer. Lid automatically closes, keep hands clear and materials off of load lock lid during wafer transfer operations.
    d. Load Lock will pump to base pressure (150mT) and then cycle purge several times before loading sample into the process chamber. If the "Manual Loader" screen appears, the transfer was either aborted mid cycle or a failure has occurred. <Exit> the manual loader screen and call the Key Operator for assistance.
    e. When transfer is complete, system will default to the Trion Main System Menu and the green "Wafer Loaded" light will appear on the screen.
    f. Wafer transfer is complete.

2) Unload Wafer (Wafer in Process Chamber)
    a. Select <Unload Wafer> (Trion Main System Menu>
    b. Load lock will pump down to base pressure (150mT) and then cycle purge several times before removing wafer from the process chamber. Once wafer has been removed from the process chamber into the load lock additional cycle purging will occur. The load lock takes 60 seconds to vent to atmosphere. Once at atmosphere, the lid will automatically open. Remember to keep hands clear and materials off of load lock lid during wafer load and unload operations.
    c. When "Unload Sequence Finished" appears, remove sample from robot end effector. Press <OK>. Lid automatically closes, keep hands clear and materials away from load lock lid during transfer operations.
    d. Select <OK> to pump load lock to base pressure. If you intend on loading another sample, select <Cancel> then follow Load Wafer sequence to load the next wafer.

3) Open Load Lock Lid – Select <Standby> then <Cancel>; Load lock will automatically vent (60s) and lid will open. Keep hands clear and materials off of load lock lid during wafer transfer operations.

Select, Run or Change Process Parameters

1) Load/Edit Recipe
    a. Select <Load/Edit Recipe> (Process System Menu).
    b. If recipe displayed is not the desired recipe, select <Recipe From Disk>. Current recipe will appear in a yellow box in the upper right hand corner. Select the desired recipe, note current recipe displayed in the yellow box will change to the recipe selected. Select <Exit>.
    c. Steps 1 and 3 are normally purge steps; step 2 is the process step. Press "Step #" <#> to open the numeric keypad. Select <2> and press enter. Note step number displayed on the "Recipe Parameters" screen is now "2". Adjust parameters accordingly; touch parameter value and a numeric keypad will appear. "Use Laser Endpoint" button is for automatic endpoint; leave off if unfamiliar with endpoint operations.
    d. When finished editing the recipe, select <Exit>.

2) Run Recipe
    a. Select desired recipe and update recipe parameters.
    b. Select <Download Recipe> to ensure that the proper recipe parameters are loaded.
    c. **Two options exist, 1) "Automatic Single Process" and 2) "Automatic Process Control".** Automatic SP requires a sample to be loaded into the process chamber. Automatic PC transfers the wafer into the chamber, completes the process and then removes the sample from the chamber automatically with minimal operator intervention.
    d. **Option 1** – First load the wafer into process chamber. After wafer is **loaded**, select <Automatic Single Process> (Trion Main System Menu) to initiate the multistep process. Process will run as programmed, if an error should occur, contact the Key Operator.
    e. **Option 2** – First remove dummy wafer from process chamber. Select <Automatic Process Control> and remain clear of load lock lid. Follow "Load Wafer" instructions described in "Load/Unload Wafer" section above. Lid will open, wafer will transfer and process automatically.
    f. **Manual Operation** – Please consult Key Operator.

9.3 Maintenance

System maintenance is not covered in this procedure. If tool's status indicator is "Green" with arrow up, the system is available for use. If the status indicator is "Red" with arrow down, the system is down, contact the Key Operator or IL maintenance personnel to inquire about tool's status.

10. SIGNATURE OF COMPLETION

By my signature below, I affirm that I:
• Have read and understand this operating procedure (OP) entitled *Operating Procedure for Trion Minilock III and Orion III Etch*
• Have read and understand the PHS/HA for this laboratory and signed signature page
• Will take the required training before working with this equipment.

Name (Printed)	Signature	Org	Date